GEORGIA INSTITUTE OF TECHNOLOGY — OFFICE OF CONTRACT ADMINISTRATION

PROJECT ADMINISTRATION DATA SHEET

(R5879-0A0) [X] ORIGINAL [ ] REVISION NO. ____

Project No. E-16-608 GTRI/~~GXX~~ DATE 2 / 19 / 85

Project Director: G. A. Pierce School/~~XXX~~ AE

Sponsor: U. S. Army Research Office
Research Triangle, NC

Type Agreement: Instrumentation Grant DAAG29-85-G-0072

Award Period: From 1/1/85 To 12/31/85 (Performance) 2/28/86 (Reports)

Sponsor Amount:	This Change	Total to Date
Estimated:	$ 235,000	$ 235,000
Funded:	$ 235,000	$ 235,000

Cost Sharing Amount: $ 60,000 Cost Sharing No: E-16-~~321~~ 322 (F5879-0A0)

Title: Helicopter Vibration Suppression Techniques

ADMINISTRATIVE DATA OCA Contact William F. Brown x-4820

1) Sponsor Technical Contact:

* Richard Hilsh
Info Processing Office
U.S Army Research Office
P.O Box 12211
Research Triangle Pk NC. 27709

2) Sponsor Admin/Contractual Matters:

T. A. Bryant
ONR - RR
Georgia Tech

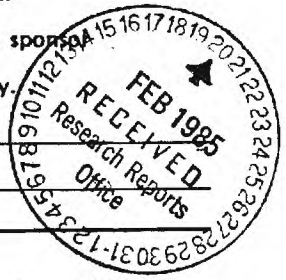
Defense Priority Rating: None shown Military Security Classification: None
(or) Company/Industrial Proprietary: N/A

RESTRICTIONS

See Attached Gov't. Supplemental Information Sheet for Additional Requirements.

Travel: Foreign travel must have prior approval – Contact OCA in each case. Domestic travel requires sponsor approval where total will exceed greater of $500 or 125% of approved proposal budget category.

Equipment: Title vests with GIT upon acquisition.



COMMENTS:

Project Director shall advise OCA (in time to notify the Sponsor by 4/1/85) if he has reason to believe that he will not expend the full amount of the grant in the acquisition of the equipment set forth in the grant.

COPIES TO:

Sponsor I.D. # 02.102.001.85.006

Project Director
Research Administrative Network
Research Property Management
Accounting
Procurement/EES Supply Services
Research Security Services
(Reports Coordinator (OCA))
Research Communications (2)
GTRI
Library
Project File
Other A. Jones

FORM OCA 4:383

GEORGIA INSTITUTE OF TECHNOLOGY OFFICE OF CONTRACT ADMINISTRATION

SPONSORED PROJECT TERMINATION/CLOSEOUT SHEET

Date 5/7/86

Project No. E-16-608 School/~~XXX~~ AE

Includes Subproject No.(s) N/A

Project Director(s) G. A. Pierce GTRC / ~~GIT~~

Sponsor U. S. Army Research Office, Research Triangle, NC

Title "Helicopter Vibration Supression Techniques"

Effective Completion Date: 12/31/85 (Performance) 2/28/86 (Reports)

Grant/Contract Closeout Actions Remaining:

- [ ] None
- [X] Final Invoice or Final Fiscal Report
- [ ] Closing Documents
- [X] Final Report of Inventions– Sent Patent Questionnaire to P. I.
- [X] Govt. Property Inventory & Related Certificate
- [ ] Classified Material Certificate
- [ ] Other _____

Continues Project No. _____ Continued by Project No. _____

COPIES TO:

Project Director
Research Administrative Network
Research Property Management
Accounting
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Research Security Services
Reports Coordinator (OCA)
Legal Services
Library
GTRC
Research Communications (2)
Project File
Other A. Jones, R. Embry

HELICOPTER VIBRATION SUPPRESSION TECHNIQUES

Semiannual Progress Report

Period:
1 January 1985 - 30 June 1985

Department of Defense Grant No. DAAG29-85-G-0072

Prepared by: G. Alvin Pierce
Principal Investigator

School of Aerospace Engineering
Georgia Institute of Technology
Atlanta, Georgia 30332

SUMMARY STATUS OF EQUIPMENT PURCHASES

This statement of equipment purchases reflects the status of all purchase orders associated with the subject DoD Grant and Georgia Tech matching agreement effective 30 June 1985.

Item	Encumbrance	Expenditure
3-Channel Exciter System:		
Zonic Corp.	---	103,280.95
Analyzer System:		
Gen Rad, Inc.	96,276.63	---
Data Acquisition Equipment:		
Hewlett-Packard Co.	25,323.20	---
Preston Scientific, Inc.	14,970.90	---
Equipment Racks:		
General Devices Co.	---	1,557.05
Signal Conditioning Amplifiers:		
NEFF Instrument Corp.	---	29,070.00
Oscilloscope Monitor:		
Tektronix, Inc.	---	10,255.00
Impulse Exciters:		
PCB Piezotronics, Inc.	---	3,160.73
Workstation:		
Eczel Corp.	---	2,158.97
	136,570.73	149,482.70
Unencumbered Balance		8,946.57
TOTAL		$295,000.00

Source of Funding	
Department of Defense	235,000.00
Georgia Institute of Technology	60,000.00
	$295,000.00

E-16-608

HELICOPTER VIBRATION SUPPRESSION TECHNIQUES

Final Report

Period:
1 January 1985 - 31 December 1985

Department of Defense Grant No. DAAG29-85-G-0072

Prepared by: G. Alvin Pierce
Principal Investigator

School of Aerospace Engineering
Georgia Institute of Technology
Atlanta, Georgia 30332

SUMMARY

The equipment purchased under this DoD University Research Instrumentation award has been used to significantly extend the research testing and analysis capabilities of the Aeroelastic Rotor Test Facility at the Georgia Institute of Technology. Presented herein is an itemized listing of the specific component systems purchased under this program. All systems have been installed in the test facility and are operational. Also included is a description of the facility and related research projects.

SUMMARY OF EQUIPMENT PURCHASES

This statement of equipment purchases reflects all purchase orders associated with the agreement of DoD Grant DAAG29-85-G-0072. These purchases are listed below by individual systems as previously described in the Financial Plan of the subject grant.

System	Cost
3-Channel Exciter System: Zonic Corporation (Mfg) Exciter Head (3) Master Controller (3) Power Supply (1) Line Control Man. (3) Phase Shifter (3) Pump Control (1) Integrator (3) Mod Pack Rack (2) Filler Panel (4) Keithley Digital Multimeter	$103,722.75
Analyzer System: Gen Rad, Inc. (Mfg) CAT 2515 (RM) 1 Mb Memory Exp. to 5-8 Ch. Exp. to 9-12 Ch. Exp. to 13-16 Ch. Datalink SDRC - Compiler/RT-11 SDRC - Modal Plus SDRC - Multi-point Random SDRC - SABBA Training Prog. Amdek Monitor 300A	96,421.63
Data Acquisition Equipment: Hewlett-Packard Co. (Mfg.) 132.1 Mb Disc (1) 1 Mb Mem. Card (1) 2 Mb Mem. Cards (1) Mem. Conn. to 4 (1) Parallel I/F (1) Multiplexer I/F (1)	40,294.10

System	Cost
Data Acquisition Equipment: (Continued) Preston Scientific, Inc. (Mfg) 16 Ch. Multiplexer (1) Sample & Hold (16) LCDAC 16 Ch. (1) Wiring for Expansion DAC Address Distr. I/F to 12006A GM-3 Chassis w/power supply Engr. Adap. Chrg.	
Equipment Racks: General Devices Co. (Mfg) Vent-Rak Cabinet (2) Caster Base (2)	1,557.05
Signal Conditioning Amplifiers: NEFF Instrument Corp. (Mfg) Amplifier (36) Amplifier Rack (3)	29,070.00
Oscilloscope Monitor: Tektronix, Inc. (Mfg) Mainframe Dual Trace Amp. (2) Dig. Time Base Camera Case	10,255.00
Impulse Exciters: PCB Piezotronics, Inc. (Mfg) Impulse Hammer Kit Mini High Freq. Kit	3,160.73
Workstation: ECZEL Corp. (Distr) Workstation Return Drawer Elect. Mod. Fixed Pedestal O/H Riser Write Board Pens (4) Ergo Chairs (4)	2,158.97

System	Cost
Remote Computer Workstation: IBM PC-XT Mod. 068 Rodime 30 MB Hard Disk Quadram Quadboard Genoa Spectrum Graphics Board Amdek 722 Monitor Toshiba P351 Printer HP 7475A Plotter Software for word processing, graphics and data base management.	8,155.00
Total expenditures	$294,795.23
Source of Funding	
Department of Defense	234,802.03
Georgia Institute of Technology	59,993.20
	$294,795.23

SPECIAL ACQUISITION CIRCUMSTANCES

It may be noted that the Financial Plan (Budget) of the contractual agreement included an item called "Rotating Machinery Analyzer" as a component of the "Analyzer System" to be purchased from Gen Rad for an estimated cost of $8,294. At the time of the agreement the "Rotating Machinery Analyzer" represented a software package being developed by Gen Rad for use on their CAT 2515 analyzer system which was purchased under this grant. This software was to be used in the Aeroelastic Rotor Test Facility to monitor various transducer signals during start-up and shut-down of the drive system. The monitoring was to provide a record for detecting incipient failures of the drive system and test articles.

Gen Rad was not able to deliver the software package within the contract period (1985 calendar year). As a consequence the decision was made to pursue an in-house development of software which will specifically satisfy our monitoring requirements. This effort is continuing. It was also decided to utilize the amount budgeted for the "Rotating Machinery Analyzer" to acquire a "Remote Computer Workstation." This would be a PC-based system which could receive experimental data or analytical results directly from the Aeroelastic Rotor Test Facility via the local area network. These data could then be conditioned and formatted for direct inclusion in technical reports. To accomplish this it was necessary to acquire a workstation with word processing, data base management and graphics capability. The specific system acquired is listed in the preceding section on Summary of Equipment Purchases as the Remote Computer Workstation.

FACILITY AND RESEARCH PROJECTS

Facility

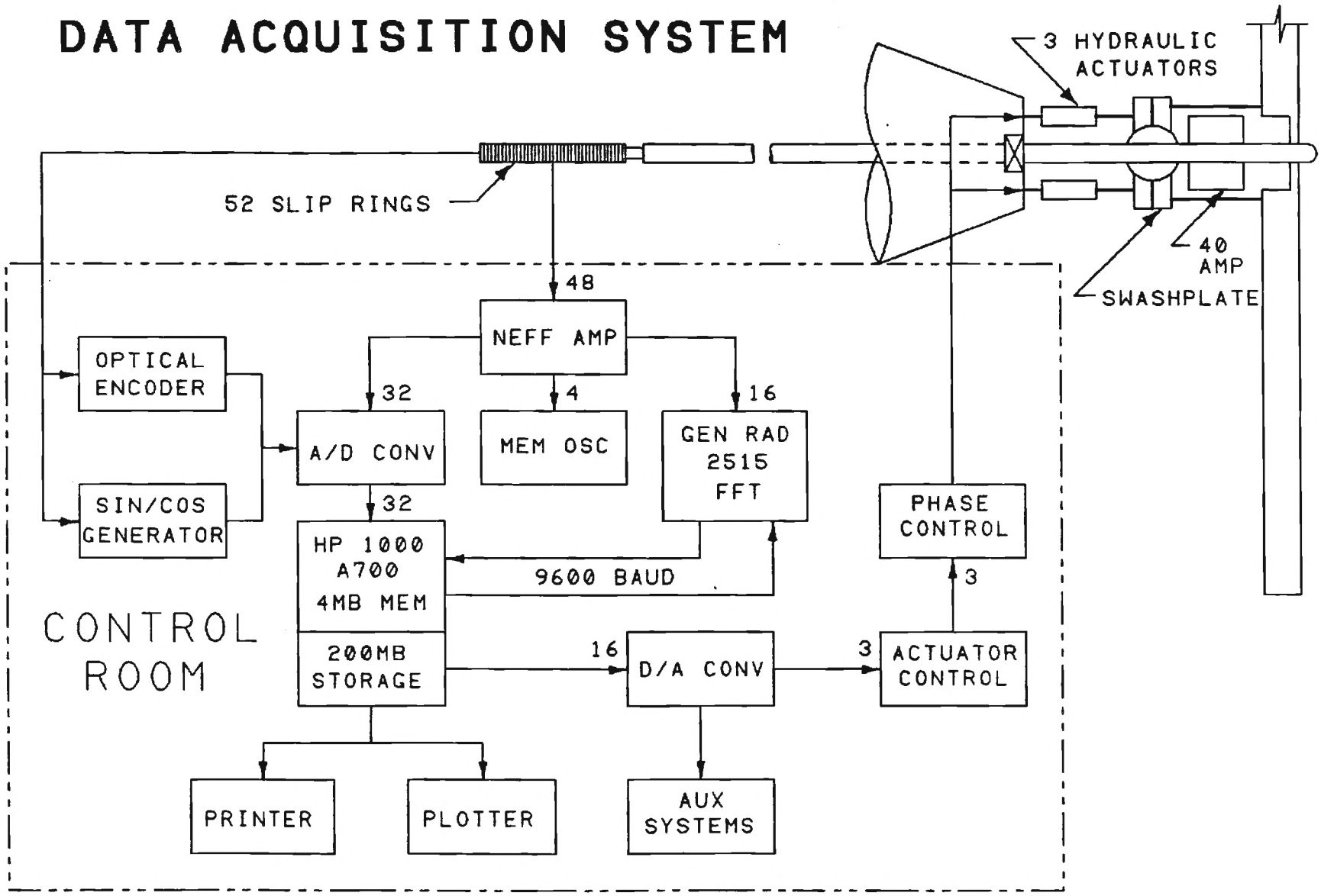
In 1982 the U.S. Army Research Office commissioned the Georgia Institute of Technology to design and construct a unique testing facility for the purpose of acquiring a comprehensive data base of aeroelastic response characteristics for scaled model helicopter rotors. This data base could then be used in subsequent correlation studies to establish the validity or deficiencies of available analytical methods for the prediction of structural dynamic and/or unsteady aerodynamic phenomena.

The facility was designed as a stationary test chamber for controlled dynamic excitation of aeroelastically scaled model rotors at rotational speeds up to 1,800 RPM as powered by a 30 hp drive system. In addition to the variable speed drive system the chamber consists of a honeycomb enclosure which surrounds the test article to prevent recirculation of the highly rotational wake. There are two sources of dynamic excitation available to the test engineer. One consists of a set of stationary air jets directed normal to the tip-path plane. A second means of excitation is a typical swashplate mechanism which is oriented by three high frequency hydraulic actuators.

The facility includes a computer based data acquisition system which is schematically illustrated on the following page. Up to 40 channels of model-mounted transducer signals can be amplified by a rotating differential-amplifier package prior to being transmitted to the control room via a 52-channel slip-ring assembly. These signals plus others can be subsequently amplified by a bank of 48 NEFF amplifiers. Of these amplifier outputs 32 channels can be processed on-line by an analog-to-digital converter for transmission to the HP 1000 A700 computer system. The HP 1000 system has 4 MB of memory and 200 MB of disk storage.

The HP 1000 computer has a FORTRAN 77 compiler and three-dimensional graphics capability. In addition to the HP 2623A graphics terminal, system outputs can be recorded on an HP 2932A printer and HP 7475A plotter. This

DATA ACQUISITION SYSTEM



output recording capability also includes a Tektronix memory oscilloscope with four channels of presentation. A 16-channel digital-to-analog converter provides test control signals generated by the HP 1000 system.

In addition to the 32 channels of data input to the HP 1000 system, another 16 channels can be received by a GenRad 2515 CAT system. This 16 channel programmable system is capable of executing numerous spectral analysis operations on the incoming data. In addition the system includes the MODAL PLUS and SABBA software of SDRC. Thus the GenRad analyzer can conduct on-line modal and damping evaluations. The capability has been included to permit high speed data transfer between the GenRad 2515 and HP 1000 systems. Consequently, GenRad outputs can be presented by the printer and plotter or stored on the HP 1000 disk system. It is also possible to conduct off-line frequency analysis of any data residing on the HP 1000 disk system.

In addition to the signal conditioning capabilities of the facility, the installation includes a three-channel high-frequency hydraulic excitation system. This Zonic excitation system permits on-line computer control of a swashplate mechanism for the dynamic excitation and control of the model rotor system in blade pitch. Applications of this excitation system in conjunction with the signal conditioning capability permits on-line control and analysis of rotor system stability and response characteristics.

Research Projects

The research program which will utilize the above facility during the period 1 July 1986 through 30 June 1987 is directed toward the measurement and correlation of dynamic response data obtained from tests of aeroelastically scaled model helicopter rotors. The model configurations to be tested are:

1. Aeroelastically Conformable Rotor (ACR) and the Baseline Blade Design (BLB) - This comprises two sets of elastic blades mounted on an articulated hub configuration. Their nine feet diameter configuration has been Mach scaled for FREON 12 at a nominal 685 RPM. These four-bladed rotors and hub are currently on site at Georgia Tech.

2. Hughes Advanced Rotor Program (HARP) - This configuration consists of a four-bladed rotor mounted on a bearingless hub design. The eight feet diameter rotor has been Mach scaled for air at a nominal speed of 1,700 RPM. The HARP model will be provided for testing by McDonnell Douglas Helicopter Co.

The three types of testing to be performed using the various rotor configurations can be summarized as follows:

1. Structural Integrity and Stability Tests - A test program will be conducted to insure the structural integrity and the flutter stability of the rotor system for progressively increased RPM and mean pitch angle. The stability tests will be based on conventional decay rates and a moving block analysis in response to dynamic swashplate excitation. These data will be correlated with analytical studies using Georgia Tech stability programs.

2. Dynamic Excitation Testing - For various RPM's and mean pitch angles a dynamic excitation of the rotor system will be provided by a programmed motion of the swashplate. The resulting structural dynamic response of the blades will be recorded for each set of test conditions. These data will be correlated with analytical results obtained from Georgia Tech response programs.

3. Higher Harmonic Control Testing - Periodic excitation of the rotor will be provided by the gust generator for various RPM's and mean pitch angles. Performance of the HHC system will be ascertained for these conditions and the effect of some of the controller parameters will also be investigated. These data will be correlated with analytical results obtained from Georgia Tech response programs.